for hunting this species were yearly despatched. The Americans called it "black whale," a denomination which, by the bye, also applies to other kinds.

Its range on the shores of America seems to have fallen a little south of that of Europe. It is in fact most probable that the whale visited the coast of Florida during the winter months, perhaps even more southern latitudes. Northwards it might be found as far as the sea is free from ice, but several circumstances seem to indicate that it preferred a temperate zone, and that its appearance on the shores of Greenland were merely migratory visits during the hot season. It may in fact be assumed that the North Cape whale made its regular migrations like the Greenland whale; in support of which I may point out that from the thirteenth to the fifteenth centuries the whale-hunting in the Bay of Biscay was carried on only during the winter months, and around America was limited to the season between November and April, at all events on the coast of New England.

What is known as to the principal haunts of this species of whale is alone based on the reports we possess of its hunting in the preceding centuries.

From the eighteenth century we hear no more about the catching of the North Cape whale in European waters, and in the beginning of the present century it also ceased to be hunted on the shores of America in consequence of its great scarcity.

It is therefore exceedingly interesting to find that the North Cape whale is again appearing on the east coast of America in such numbers that its catching is being resumed.

On the coasts of Europe the whale has only been discovered twice during this century, viz. in 1854, when a young one was caught at Pampeluna, the mother escaping; and in 1877, when the carcass of one—thirty-six feet in length—was cast ashore in the Bay of Toronto in Southern Italy. The skeleton of the former was brought to Copenhagen by the late Prof. Eschricht, where it now is.

The discovery which I made in 1882 on the shores of Finmarken of remains of this species of whale, hunted there by the Dutch in the sixteenth century, gave rise to further investigations as to the probable reappearance also in these parts of the North Cape whale, and from reports and circumstances brought to my knowledge, I feel convinced that considerable numbers of the North Cape whale again yearly appear on the coast of Northern Norway, where they were once so common. I must indeed regret that to ascertain with positive certainty whether this is a scientific fact is very difficult for a scientist whose stay in a certain part for scientific research is limited to a month or so. I hope, however, to obtain substantial proof of my belief at no very distant date.

For a figure of the North Cape whale I may refer the reader to that published in May 1883 in the *Bulletin* of the American Museum of Natural History, New York.

The University, Christiania G. A. GULDBERG

MEASURING EARTHQUAKES

I.—METHODS

IT is difficult to define the word earthquake in terms which will not cover cases to which the name is inappropriate. To say that an earthquake is a local disturbance of the earth's crust, propagated by the elasticity of the crust to neighbouring portions, is true, but the definition does not exclude, on the one hand, such tremors of the soil as are set up by the rumbling of a carriage, by the tread of a foot, or even by the chirp of a grasshopper, nor, on the other, those slow elastic yieldings which result from changes of atmospheric pressure, from the rise and fall of the tides, and perhaps from many other causes. One writer, in his definition of the word, limits the name earthquake to disturbances whose causes are unknown—a course open to the obvious objection that if the study of earthquakes ever advanced so far as to make the causes perfectly intelligible we should, by definition, be left with no earthquakes to study. It must be admitted, however, that in the present state of seismology this objection has no force, for in assigning an origin to any disturbance likely to be called an earthquake, we have, so far, been able to do little more than guess at possibilities. The more practicable task of determining what, at any one point within the disturbed area, the motions of the ground during an earthquake exactly are has lately received much attention, and in this department of seismology distinct progress has been made.

Apart from its scientific interest, this absolute measurement of earthquake motion is not without its practical use. Though the recent sharp earthquake in the Eastern Counties has reminded us that no part of the earth's surface can be pronounced free from liability to occasional shocks, these occur so rarely in this country that English builders are little likely to let the risk of an earthquake affect their practice. If Glasgow or Manchester had

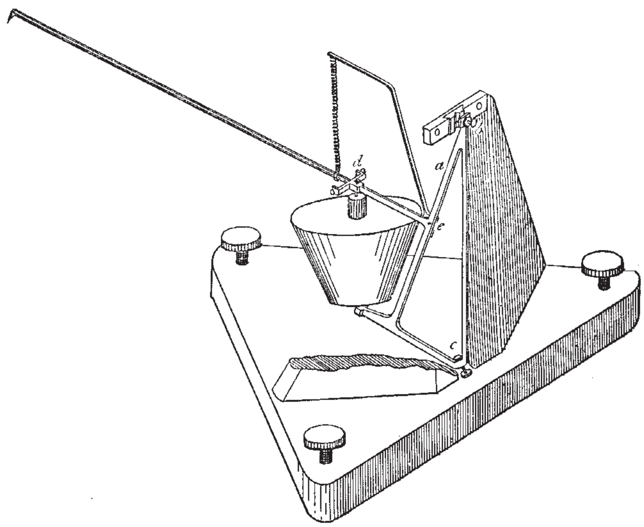

Fig. 1

been shaken instead of Colchester, the chimneys of the mills would, we suppose, have risen again in a few weeks no less tall than before. The case is different in an "earthquake country," such, for example, as some parts of Japan, where the present writer had the good fortune to experience, during five years, some three hundred earthquakes. Where the chances are that a structure will have to stand a shock, not once in a few centuries, but half-a-dozen times a month, the value of data which will enable an architect or engineer to calculate the frequency and amplitude of the vibrations, and the greatest probable rate of acceleration of the earth's surface, does not need to be pointed out.

To know how the earth's surface moves during the passage of a disturbance we must obtain, as a standard of reference, a "steady-point," or point which will remain (at least approximately) at rest. This is a matter of no small difficulty, for (as will be shown in a second paper) the motions during any single earthquake are not only very numerous but remarkably various in direction and extent. Most early seismometers were based on the idea that an earthquake consists mainly of a single great impulse, easily distinguishable from any minor vibrations which may precede or follow it. The writer's observa-

tions of Japanese earthquakes do not bear this out. They show, on the contrary, during the passage of almost every earthquake, scores of successive movements, of which no single one is very prominently greater than the rest. Moreover, the direction in which a particle vibrates is so far from constant that it is usually impossible to specify even roughly any particular direction as that of principal movement. For these reasons attempts are futile to obtain knowledge of earthquake motions from instruments intended to show only the greatest displacement or "the direction of the shock." The indications of such instruments are, in fact, unintelligible, and it is safe to say that no seismometer is of value which does not exhibit continuously the displacement of a point from its original position during the whole course of the disturbance. The value of the observation is enormously increased if, in addition to the amount and direction of the successive displacements being shown, these are recorded in their relation to the time. We can then, besides seeing the frequency of the vibrations, calculate the greatest velocity of the motion of the surface, and also its greatest rate of acceleration—an element of chief importance in determining an earthquake's capacity for mischief, since in a rigid and rigidly founded structure the shearing force through the base is equal to the product of the acceleration into the mass, and the moment tending to cause overthrow is that product into the height of the centre of gravity.[1]

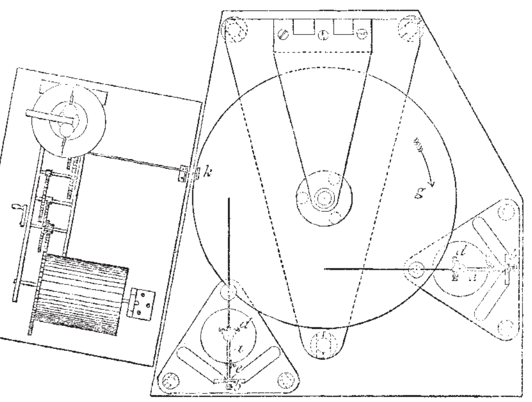

Fig. 2

Seismographs used during the last three or four years by the writer and others in Japan give a record of the earth's motion during disturbance by dividing that into three components, along the vertical and two horizontal lines. In the writer's apparatus these three are independently recorded on a revolving sheet of smoked glass, which is either maintained in uniform rotation, ready for an earthquake to begin at any moment, or is started into rotation (by help of an electro-magnetic arrangement) by the earliest tremors of the earthquake itself. The relative position of the marks on the glass serves to connect the three components with each other, and a knowledge of its speed of rotation connects them with the time. It is sufficient that the "steady-point" for each of the three components should be steady with respect to motion in one direction only. It may move with the earth in either or both of the other two directions, and in fact it is generally most convenient to provide three distinct steady-points, each with no more than one degree of freedom.

In that case each steady-point is obtained by pivoting a piece about an axis fixed to the earth, and in nearly neutral equilibrium with respect to displacements about the axis of support. When the earth's surface shakes in the direction in which the piece is free to move, the support, which is rigid, moves with it, but the centre of percussion of the pivoted piece remains approximately at rest, and so affords a point of reference with respect to which the earth's movements may be recorded. If we could get rid of friction, and if it were practicable to have the equilibrium of the pivoted piece absolutely neutral, the centre of percussion would remain (for small motions) rigorously at rest even during a prolonged disturbance. But there must be some friction at the axis of support and also at the tracer which records the relative position of a point moving with the earth and the steady-point of the seismograph. And the pivoted mass must have some small stability, to prevent a tendency to creep away from its normal position during a long continued shaking, or in consequence of changes of the vertical. If, however, the mass be so nearly astatic that its free period of oscillation is much longer than the longest period of the earthquake waves, and if great care be taken to avoid friction, the centre of percussion behaves almost exactly as a true steady-point with respect to all the most important motions of even a very insignificant earthquake. The effective inertia of the system may be further increased by pivoting a second mass on an axis passing through the centre of percussion of the first piece and parallel to the axis of support. An instrument designed on these lines in which the pivoted pieces in neutral equilibrium were

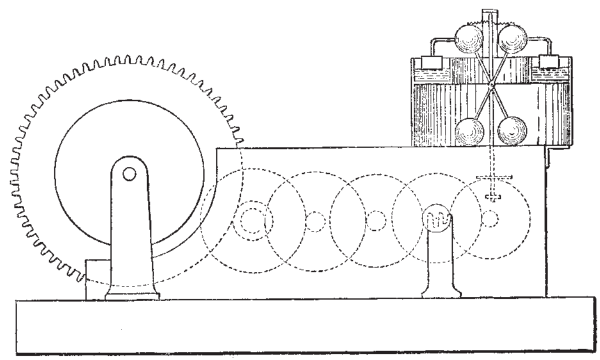

Fig. 3

two light frames supported as horizontal pendulums at right angles to each other, and with a massive bob pivoted at the centre of percussion of each, gave (in 1880) the earliest complete records of the horizontal movement of the ground during an earthquake. A description of it has been given in the *Proceedings of the Royal Society*, No. 210.

Figs. 1 and 2 show this seismograph, improved in many of its details. The form shown is one which has done excellent service in a seismological observatory which the writer was enabled to establish in the University of Tokio, through the interest of the Japanese directors. A similar instrument has also been supplied to the Government of Manila. Fig. 1 shows one of the two horizontal pendulums with a portion of one of its upright supports removed. The axis of support (which slopes very slightly forward to give a small degree of stability) is formed by two steel points, *b* and *c*, working in an agate V-groove and a conical hole. The frame of the pendulum is a light steel triangle, *a*, the effective inertia being given almost wholly by a second mass pivoted at *d* on a vertical axis which passes through the centre of percussion of the frame. The tracer, which serves to magnify as well as to record the motion, is a straw, tipped with steel, and attached to the pendulum by a horizontal joint at *d*, which allows it to accommodate itself to any inequalities in the height of the glass plate on which its distant end rests. A portion of its weight is borne by a spring, adjustable by a

[1] The case is different and much less simple where the structure is so flexible as to have a period of free vibration comparable with the periods of the earthquake vibrations.

clamp at *e*, by which the pressure of the tracer on the glass plate may be reduced to an amount just sufficient to scratch off a thin coating of lamp-black with which the glass is covered. In Fig. 2 the two pendulums are seen in plan, with their tracing pointers touching the glass plate *g* at different distances from its centre. The plate and pendulums are mounted on a single base, which is very rigidly secured to the top of a broad post, stuck firmly in the earth and projecting only a few inches above the surface. Continuous rotation is communicated to the plate by a friction-roller, *k*, held in a slot guide and connected by a universal joint to one of the arbors of a clock, which is wound up once a day. Government by an escapement being out of the question, the clock is controlled by a fluid-friction governor connected to the wheel train, also by friction gear, as shown in Fig. 3. The balls are four in number to prevent disturbance of them by an

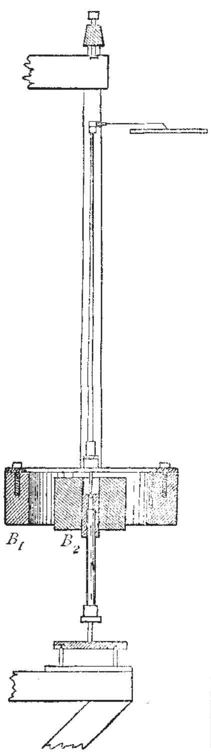

Fig. 4

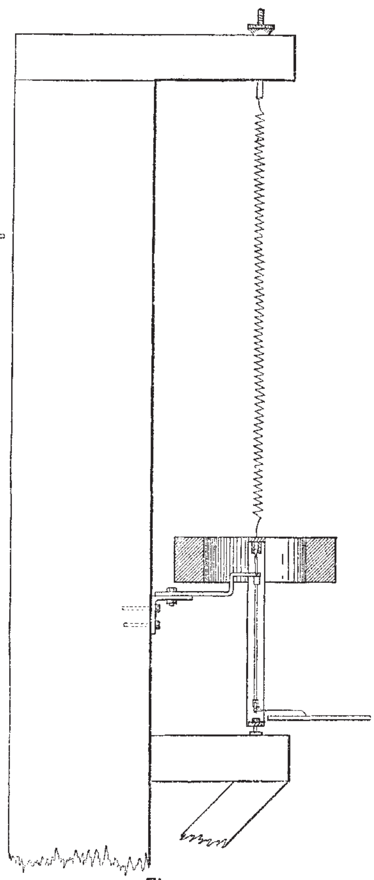

Fig. 5

earthquake. The vanes dip into oil, and are drawn back by two springs which tie them to the spindle.

When the earth shakes, the axis, *d*, of each bob remains sensibly at rest as regards components of motion perpendicular to the corresponding pendulum, and the tracing point is therefore displaced over the glass plate, in the direction of the plate's radius, through a distance which in this case is four times the motion of the earth. So long as no earthquake occurs each pointer traces over and over again a single circle on the plate. The circle frequently tends to widen inconveniently, especially if the pendulum is very nearly astatic. This is in part at least due to such changes of the vertical as have been observed by d'Abbadie, Plantamour, G. H. Darwin, and others. The plate consequently requires frequent attention, and where that cannot be given, an electric starting arrangement is to be preferred. When an earthquake has occurred, the plate is removed, varnished, and photographed by using it as a "negative."

The bob of each pendulum may of course be rigidly attached to instead of pivoted on the pendulum frame. In that case the centre of percussion of the frame and bob together (which will then be a little farther from the support than the centre of the bob) will be the steady-point. The writer, however, prefers the arrangement described above, which gives great compactness and a maximum of effective inertia, and which has the advantage of making the position of the steady-point at once determinate.

It would take too much space to describe or even to enumerate the many other devices which have been suggested to secure a steady-point by various methods of astatic support,[1] leaving one, or in some cases two, degrees of freedom to move horizontally. The horizontal

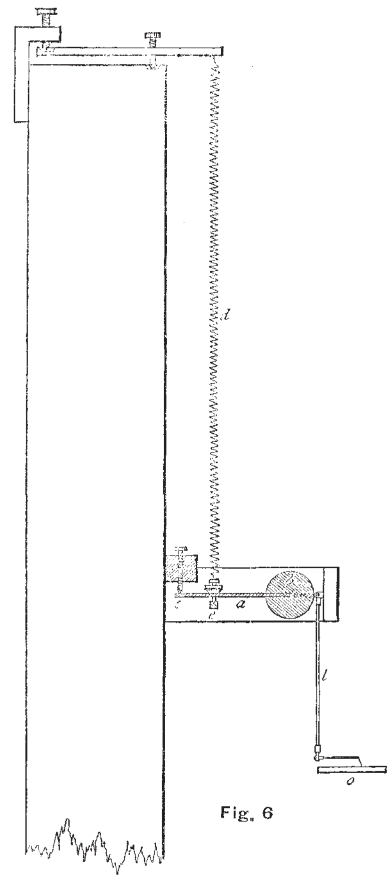

Fig. 6

pendulum has been modified by substituting a flexible wire and spring for its rigid pivots, thereby avoiding all but molecular friction at the axis of support. Spheres and cylinders, free to roll on plane or curved surfaces with or without a slab above them, have been tried, but their friction is excessive. The approximate straight-line motions of Watt and of Tchebicheff have been pressed into the service as means of suspending a mass with freedom to move in a horizontal path. The common or vertical pendulum, an old favourite with seismologists, has suffered many transformations in the effort to reduce its stability, which is preposterously great unless we make the pendulum very long. A 20-foot pendulum consisting of a cast-iron ring weighing half a hundredweight, hung

[1] See papers by Gray, Milne, the writer, and others in the *Transactions of the Seismological Society of Japan*, vols. i. to vi.; or a memoir on "Earthquake Measurement," published a year ago by the University of Tokio.

by three wires from a rigid tower, has done good work in the writer's observatory, but such an instrument has obvious drawbacks. Fig. 4 shows an arrangement, also used by the writer, and called a "duplex pendulum." A common pendulum with a ring bob, B_1, is connected to an inverted pendulum, B_2, by a ball-and-tube joint, which compels the bobs to move horizontally together. The combination can be made as nearly astatic as may be desired by proportioning the masses of the bobs to the lengths of the suspension-rods. The inverted pendulum stands on a joint which gives two freedoms to rotate but prevents twisting about a vertical axis; an extension of its rod upwards forms the multiplying arm, and carries a tracing pointer.

Another plan is shown in Fig. 5, which may be described as a duplex pendulum with a single bob, whose weight is borne partly by a socket below and partly by a spring from a support above. Any one of these instruments affords a single steady-point with respect to all motions in azimuth. Their principal use is to give "static" records of the horizontal motion, that is, records traced on *fixed* plates, which show at a glance the changes in direction of displacement during the occurrence of an earthquake.

In attempting to register the vertical component of earthquake motions, we meet with the difficulty that the weight of the mass whose inertia is to furnish a steady-point acts in the direction in which freedom of motion is to be retained. A weight hung by a spiral spring from a support above it is too stable to act as a seismometer, unless the spring be impracticably long. A horizontal bar fixed to a wall by a flexible joint and loaded at its end—an old device used by the British Association Committee at Comrie in 1842—is open to the same objection. If the loaded bar is rigid, but pivoted about a fixed horizontal axis, and held up by a spiral spring near the axis of support, we obtain a much slower period of free oscillation than if the spring were directly loaded with a weight which would stretch it to the same extent. Mr. Gray has rendered this device as nearly astatic as may be desired by adding a small tube containing mercury, whose effect is to increase the load when the bar goes down and to decrease it when the bar goes up. Another and simpler way of attaining the same result is shown in Fig. 6, which represents the vertical seismograph used in Japan by the present writer. There *a* is a horizontal bar pivoted about a horizontal axis on two points at *c*, with a heavy bob, *b*, whose weight is borne by a pair of springs, *d*. But the upward pull of the springs, instead of being applied to the bar in the line joining the axis *c* with the centre of gravity, is applied *below* that line by means of the stirrup *e*. Consequently, if the bar goes down, the pull of the springs, although increased above its normal value, is applied nearer to the axis, and (by properly adjusting the depth of *e* below the bar) the moment of the pull of the springs may thus be kept as nearly equal to the moment of the weight as may be desired—a condition which of course secures astaticism. The centre of percussion of the loaded bar is the steady-point, with respect to which the vertical motions of the ground are recorded by the multiplying lever *l* on the rim of a revolving glass plate, *o*, which may be the same plate as that which receives the record of the two horizontal components.

The instruments which have been briefly described succeed in registering very completely all the movements of the ground at an observing station during the occurrence of an ordinary earthquake, and some of them could be adapted with little difficulty to the registration of violent convulsions. It would be outside the scope of this paper to deal with the appliances by which Rossi and others have investigated those minute and almost incessant tremors of the soil whose very existence no observations less fine and careful would serve to detect.

J. A. EWING

NOTES

THE meeting for organisation of the American Association for the Advancement of Science will be held on Thursday morning, September 4; and on Friday evening, September 5, after the address of the retiring President (Prof. Charles A. Young, of the College of New Jersey), a general reception will be tendered by the citizens and ladies of Philadelphia to the members of the British and American Associations, and the ladies accompanying them. The British Association has been cordially invited, both by the American Association, to take part in their proceedings, and by the Local Committee representing citizens of Philadelphia, to accept the warm welcome which will be tendered them during the joint session. The Local Committee for the Philadelphia meeting is divided into a number of sub-committees, which have been specially created to render the stay of their visitors agreeable. It is earnestly requested that every one who intends to participate in this meeting will send his name, together with the number of ladies and gentlemen in his party, at as early a date as possible, to Dr. Persifor Frazer, Secretary of the Committee on Invitations and Receptions, 201, South Fifth Street, Philadelphia. During the week occupied by the session a number of receptions, entertainments, and excursions will be given, and a day will be set apart for the examination of the International Electrical Exhibition, to be held at Philadelphia, under the auspices of the Franklin Institute, and commencing September 2. By an arrangement between the Canadian and United States trunk lines, the members of the British Association will be furnished with first-class passage from Montreal to Philadelphia and return for 15 dollars (3*l*. 1*s*. 8*d*.), or for the single trip from Montreal to Philadelphia for 9 dollars (1*l*. 17*s*.). It is to be hoped that these rates will be further reduced before the members of the British Association will be ready to take advantage of them.

THE Executive Council of the International Health Exhibition have determined to hold an International Conference on Education in connection with the Education Division of the Exhibition: they have appointed a Committee of Management, who have drawn up a programme. For convenience of discussion all papers to be read will be printed beforehand, and they will subsequently be published by the Executive Council. Persons desirous of attending the Conference are invited to send in their names to Mr. R. Cowper, Secretary to the Committee of Management, International Health Exhibition, South Kensington, to whom any inquiries can be addressed. The following are the subjects for discussion:—1. Conditions of Healthy Education. 2. Infant Training and Teaching: (*a*) Kindergarten; (*b*) Instruction generally. 3. Technical Teaching: (*a*) Science; (*b*) Art; (*c*) Handicrafts; (*d*) Agriculture; (*e*) Domestic Economy. 4. Teaching of Music in Schools. 5. Museums, Libraries, and other Subsidiary Aids to Instruction in Connection with Schools. 6. Training of Teachers. Under this head will be considered the right professional preparation for teachers in (*a*) elementary, (*b*) intermediate and higher, (*c*) special and technical schools. 7. Inspection and Examination of Schools: (*a*) by the State; (*b*) by the Universities; (*c*) by other public bodies. 8. Organisation of Elementary Education. 9. Organisation of Intermediate and Higher Education. 10. Organisation of University Education. 11. Systems of Public Instruction in various Countries.

THE Albert Medal of the Society of Arts has been awarded by the Council of the Society, with the approval of the Prince of Wales (the President), to Capt. James Buchanan Eads, "the American engineer, whose works have been of great service in improving the water communications of North America, and have thereby rendered valuable aid to the commerce of the world."